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Biological Purification System : Integrated Biogas from Small Anaerobic Digestion and Natural Microalgae

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Abstract

Photosynthetic pigments, including chlorophyll, have an important role since they provide the oxygen and the source of energy for all living things. Plant and algae growth is affected by the photosynthesis speed which depends on the availability of carbon dioxide (CO_2). This paper reports on the pilot plant scale study of the impact of 20 % to 50 % CO_2 on biogas into the growing medium of microalgae which obtained bio-methane purification results as gaseous bio-fuels. Research material was produced from the *Jatropha curcas* Linn. husk biogas digester and a 0.15 m³ HDPE drum was used as a purification. The purification tank was filled with Catfish (*Clarias gariepinus*) farm water which grew "wild" microalgae naturally. The water was fed from the top with continuous flow of (16 to 31) $L \cdot min^{-1}$ and the biogas was fed from the bottom at (18 to 29) $L \cdot min^{-1}$. CO_2 level data of biogas was measured by orsat apparatus and processed with t test. The results achieved average efficiency reduction levels of CO_2 on 50 % in two cycles (24 % in the first and 26 % in the second).

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Keywords: Biological purification; bio-methane; bio-refinery; CO_2 levels; microalgae.

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Nomenclature

LPG	liquefied petroleum gas	**IDR**	Indonesian Rupiah
JcL	*Jatropha curcas* Linn.	**trillion**	10^{12}, Tera (T)
HDPE	high-density polyethylene		

1. Introduction

Kompas Daily, February 28, 2013 reported that since 2006 Pertamina suffered a loss of IDR 16 trillion as a result of 12 kg LPG selling under economic price[1]. Based on 2012 financial report audit, the Pertamina business of 12 kg LPG recorded losses of IDR 5 trillion[2]. Kerosene conversion has made Indonesia dependent on the import of LPG about 60.6 %[3]. Dependence on imports is harmful in energy security because of the LPG availability in the world is not big, it is only produced from approximately 8 % from natural gas and 8 % from petroleum refineries[4]. Related to the limited availability, Aep Saepudin, an Indonesian Institute of Sciences expert suggested to use biogas as LPG substitution[4]. The consideration for this case are: biogas is categorized as modern cooking oil[5]; efficient biomass conversion processes[6,7]; minimizing global warming and not competing do with food crops[8,9]; Indonesia is rich in biomass as feedstock biogas and gaseous biofuels usage is relatively broad[10]; relatively simple technology, household appliances can be made in Indonesia, and the tropical climate in Indonesia supports the anaerobic process with low cost[11]; minimizing the contamination of ground water[12], producing fertilizer with rich organic nutrients[13,14] and repairing material of soil fertility.

On the other hand, biogas has weaknesses, among them is biogas heat generating effectiveness (2 830 kcal) is lower than LPG (6 530 kcal)[15]. Biogas effective heat can be increased by removing some impurities, mainly CO_2 which in biogas composition level constitutes 20 % to 50 %[16,17], by performing purification (upgrading, enrichment, scrubbing, stripping, capture, cleaning-up). There are a number of purification methods that have been applied in some countries, namely: absorption of liquids into the physics/chemical; adsorption on the surface of a solid adsorbent; membranes separation; cryogenic separation; and chemical change[18]. However, these technologies are only efficient for large-scale biogas (industrial)[7]. Reference[19] shows that the cost to purify biomethane for household scale is three times higher biomethane for than biogas production cost.

Biological purification technology is worth examining because it has double impact. Microalgae, *Scenedesmus* sp., in laboratory experiments using biogas slurry as growing medium and biogas are given periodically generating 21 % of CO_2 compared with 24 % of control[20]. *Arthrospira* sp., *Chololera vulgaris* SAG 211-11b, *Chlorella* sp. MM-2, *Chlorella* sp. MB-9, *Chlorella vulgaris* ARC 1, *Chlamydomonas* sp. and *Scenedesmus* sp. were reported as a positive synergy with biogas[21-27]. Gemstone Team, the University of Maryland studies on the efficiency of biogas purification with microalgae, *Chlorococcum littorale* and *Phaeodactylum tricornutum*[28]. However, previous studies[20-27] used pure cultures of microalgae even mutant which might not be applied to small-scale digester households, especially in rural areas of Indonesia.

Biological purification applied biorefinery concept[29], namely the integration of microalgae and biogas. Growth of microalgae needs water, air, nutrients, and CO_2 for photosynthesis process. CO_2 is the limiting factor in the cultivation of algae because the level of CO_2 in the air is approximately 0.0300 % to 0.0387 %[30-34]. Reference[32] showed that partial CO_2 pressure in the air is not sufficient (0.032 kPa) to achieve high growth rates, since the optimal value is 0.1 kPa. CO_2 is the dominant nutrient in algae growth. Stoichiometrically the CO_2 demand in algae varies between 1.65 up to 2 $CO_2 \cdot kg^{-1}$ dry biomass[32]. Reference[29] showed that 1 kg of micro-algae requires about 1.8 kg to 2 kg CO_2. This data was supported by some research[33-35], 1 t algae biomass production requires about 1.8 t CO_2. Biogas contains CO_2 levels of 20 % to 50 %, as well as biogas digesters which produce nutrient-rich slurry. The integration was expected to have positive synergy that spurs the growth of microalgae as an available alternative of other biofuel feedstocks as well as purification of biogas into biomethane at low cost.

2. Material and methods

2.1. Materials

The preliminary study was conducted at the research garden of PT Bumimas Ekapersada, Bekasi, West Java, from July to October 2012. The biogas was produced from the two-phase digester used capsule husk *Jatropha curcas* Linn. (JcL) as feedstock[11,36]. The Catfishes (*Clarias gariepinus*) were maintained in the pond with an area of 2 m × 1.5 m × 1 m. The pond was filled with 50 % river water and 50 % biogas digester slurry outlet. The Catfishes were fed with a mix of JcL seed cake which has been detoxified[37,38] in the synergy of food and energy systems. Algae grow naturally / wildly in the catfish ponds and Algae identification was performed in Microalgae Laboratory of Surfactant Bioenergy Research Centre (SBRC), Bogor Agricultural University, IPB-Bogor, West Java.

2.2 Instrumentation

HDPE drum was used as a purification tank with working volume of 0.15 m^3. Schema and diagram of purification tank are shown in Figure 1 and Figure 2. CO_2 levels were measured by biogas orsat apparatus, in accordance with standard two holder procedures. Biogas was accommodated in a HDPE plastic holder of 2 m^3 capacity. The biogas was transferred to bottom of purification tank and released from the top of purification tank. An electric pump of 50 $L \cdot min^{-1}$ capacity was used for catfish pond water recirculation.

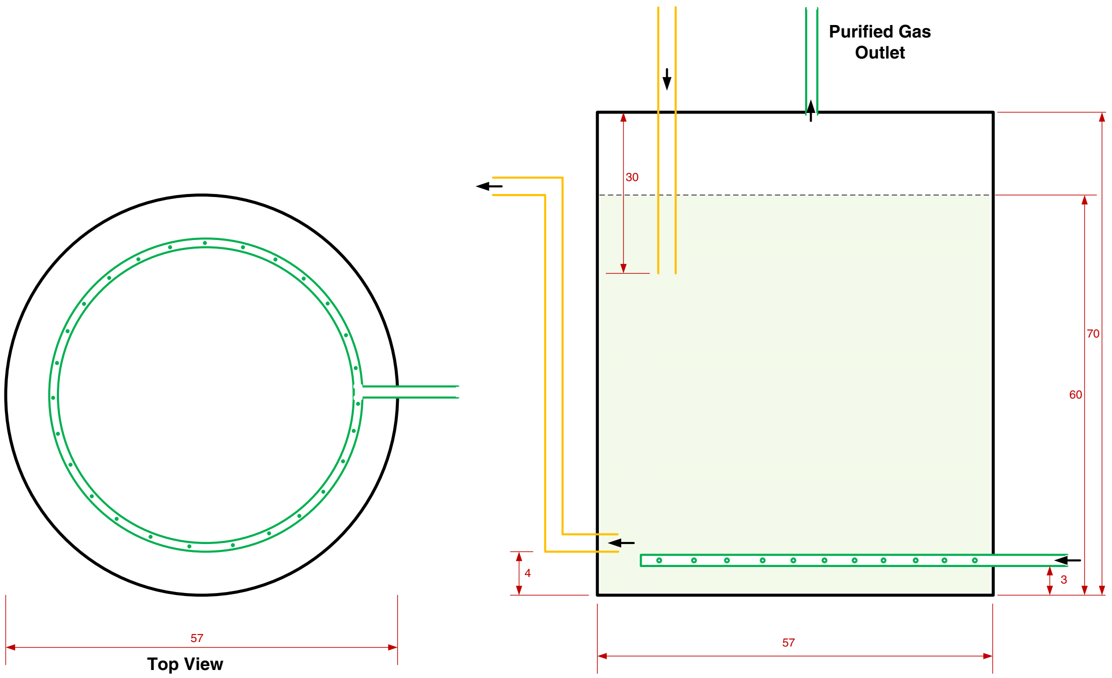

Fig. 1. Schema of purification tank.

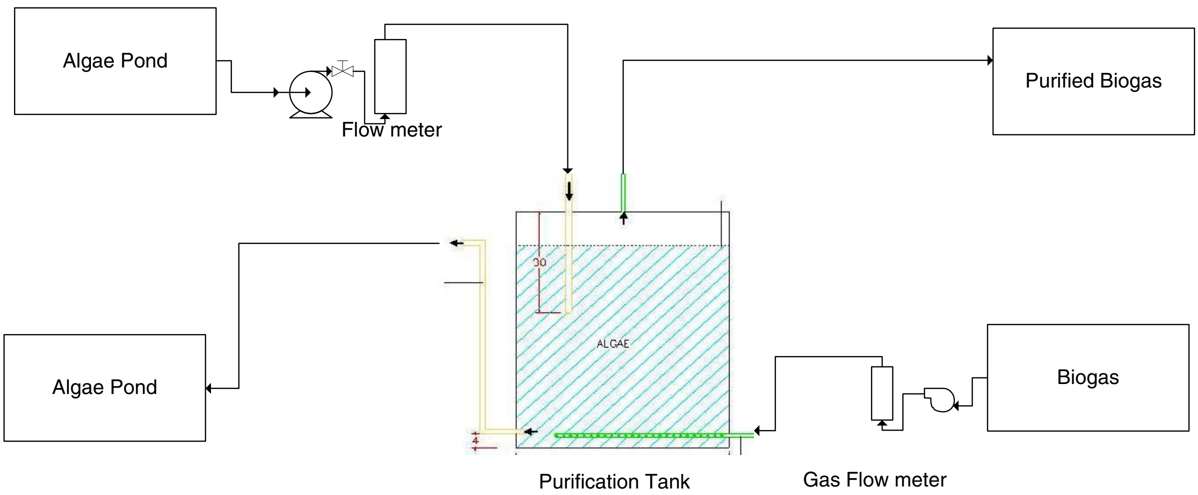

Fig. 2. Diagram of purification tank.

2.3 Procedure

In the first step, the CO_2 levels of the biogas sample in the A holder were measured. The biogas from the A holder with 2 m^3 of capacity was pressed continuously by ballast for entry into the bottom of purification tank. Purification tank was filled with 0.15 m^3 water from the catfish pond which was overgrown with algae. Catfish pond water was pumped continuously into the purification tank from the top and exited through the hole in the bottom to get back into the pond. The Pump capacity was set equal to the biogas discharge income. Biogas bubbles from the bottom of the tank will be contacted with water pond overgrown with algae and further out of the hole in the top into the B holder head with 2 m^3 capacity. The CO_2 levels in the B holder were measured by orsat apparatus. This procedure was referred to The First Cycle. The Second Cycle procedure performed the same as the first cycle, namely biogas in the B holder was pressed into purification tank and was accepted by the A holder. CO_2 levels in the second cycle in the A holder were measured by orsat apparatus. The research was conducted six times at intervals of two days. T test was performed to analyze the first cycle and the second cycle. CO_2 capture efficiency (%) was calculated with the following Equation 1[22] :

$$\frac{\text{Influent of } CO_2 \text{ - Effluent of } CO_2}{\text{Influent of } CO_2} \text{ x } 100\% \qquad (1)$$

3. Results and discussion

Identification of catfish pond water showed that overgrown microalgae in the pond such as *Scenedesmus* sp.*, Nitzchia* sp.*, Tetraspora* sp.*,* and *Selenastrum* sp. showed the number of (178 to 315) cells · mL^{-1}. Biogas flow measurement showed the number of (18 to 29) L · min^{-1} and discharge measurements showed the number of pond water recirculation of (16 to 31) L · min^{-1}. Measurement of CO_2 capture efficiency (%) according to the Equation 1 is shown in Figure 3. Figure 3 shows that the "natural /wild algae" was able to reduce the levels of CO_2 in the biogas with the 1st treatment cycle number of 24 %, the 2nd treatment cycle number of 26 %, so with two times circulation of CO_2 reduction of 50 % was gained then there was no significant difference on the result of the t test administered to the first cycle and then to the second cycle was gained CO_2 reduction of 50 %. T test on the 1st cycle than 2nd cycle was no real different. It can be concluded that biogas entry can be offset by the discharge pool water recirculation (algae).

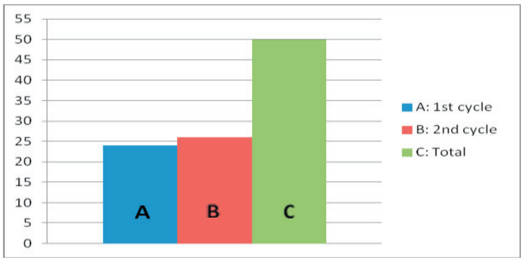

Fig. 3. The average CO_2 capture efficiency (%) in the1st cycle, 2nd cycle, and total cycle.

The percent efficiency rate of 50 % as the number of performance "natural /wild algae" is lower than the previous study[21] which is mutant strain of microalga *Chlorella* sp. MM-2 was reportedable to approximate 70 % on cloudy days and 80 % on sunny days. Similarly, it is lower than *Chlorella vulgaris*, SAG211-11b which was reported to be able to reduce the amount of 97.07 % CO_2[26]. However, 50 % percent efficiency in this preliminary study was higher than the performance of micro algae *Arthrospira* sp.which was reported be able to reduce the levels of CO_2 by 2.5 % to 11.5 %[22].This study is ongoing, particularly improving purification tank, for improving CO_2 capture efficiency that will impact directly on elevated levels of methane. The benefit of this improvement is time reduction of biogas stove in the kitchen as shown in previous studies[39,40]. Similarly, observation of H_2S reduction levels being made to minimize corrosion, which in previous studies it was reported that micro algae *Arthrospira* sp. and *Chlorella vulgaris*, SAG211-11b produce[24,26].

4. Conclusion

This preliminary study concludes that "natural / wild algae" growing in catfish ponds can be used as a biological purification of biogas. 1st treatment cycle was able to reduce the levels of CO_2 in the biogas in the amount of 24 %, in the 2nd treatment cycle the number is 26 %, so with the circulation conducted twice, CO_2 reduction of 50 % was gained. In view of the results of this study, integration technology of catfish ponds and biogas digesters in rural areas can be recommended to get energy and sustainable food.

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